V1201/V1202 Evolution

Introduction

Prior to the arrival of OV-099 Challenger at KSC, ground processing leak checks were performed on a traditional point to point basis. These leak checks were performed at mechanical threaded or flanged joints and at welded or brazed joints. Troubleshooting following Challenger's FRF's resulted in the identification of a serious hydrogen leak that eluded detection through traditional leak check methods. After the Challenger FRF, confidence in the point to point leak checks was shaken as post test data evaluation concluded the undetected leak would have exceeded the ascent flammability limit (Back-up charts 1 and 2). A new end to end total system leak check was needed to guarantee leakage rates that would keep the Main Propulsion Cryogenic systems below the ascent flammability limit. The widely accepted flammability limit of H2 in air is 4% which correlates to an ascent limit for hydrogen of 57,000 to 59,000 scim. The need to limit ambient leakage to avoid this ascent flammability limit was considered priority one by the system engineers.

Initial Procedures

At that time, leak checks of the cryogenic connections at the Tail Service Mast to the Orbiter Flight Quick Disconnects were accomplished by pressurizing the internal fluid carrier with helium and purging a control area (via an enclosed torque box) with a known flow rate of nitrogen. The HGDS system was then used to sample the helium/nitrogen concentration of the purge effluent exit flow. A very accurate leak rate could then be calculated based of the percent of helium detected in the nitrogen purge gas. This leak check philosophy was used in deriving the Helium Signature Test which would be able to not only characterize total joint leakage, but also any external leakage associated with piping or component body assemblies. The idea was to seal the aft fuselage (the control volume), pressurize the internal propellant fluid systems with helium, use the ECS aft purge air as a mixing and transport system, and via the HGDS monitor the purge effluent outlet flow for helium concentration deltas.

This concept was developed as a horizontal (OPF) test designated V1201 and a vertical (VAB/PAD) test designated V1202. Whereas the basic concept was similar, each configuration presented its own specific problems and setbacks:

V1201

- Since there was no OPF Haz Gas monitoring system, a mass spectrometer (M/S) had to be used to monitor the helium concentration deltas. The M/S machines suffered a run time vs. fidelity problem and the readings would drift over time. Also, when systems were pressurized for long periods of time the OPF background helium would increase and start to mask the test results. The conservatism with the introduced error of this test made all but a zero reading suspect.

- The Orbiter aft fuselage was rarely in a flight configuration which if not constantly monitored could lead to problems with the control volume.

V1202

- The old HGDS had to constantly be corrected for the Test, span and zero gases.
- GO2/GH2 systems had to be isolated from the Tank via blanking plates in order to pressurize the systems to 400 psig.

Test

Setups for the HST consisted of:

- Jumpering the Topping and Hi-Pt Bleed hydrogen sub-systems to the main LH2 trunk system via flexhoses. Then leak checking the installed flexhoses prior to test start.
- Configuring one aft PVD vent door and its corresponding HGDS sense port to sample the aft fuselage outlet flow. Connection of a aft fuselage delta pressure gage.
- Preping the Mass Spec Machine (OPF) or the HGDS (VAB/PAD)
- Sealing any aft fuselage openings due to missing hardware
- Installing PVD purge ducts into Orb/ET disconnect areas (areas of low mixing)
- Setting up the helium injection test panel and three tygon test hoses
- Configuring the SSME's to lockup and supplement Hot Gas pressure
- Installing blanket plates (VAB/PAD)
- Configuring Payload Bay doors or mid body vent doors to prevent PLB purge from passing thru 1307 bulkhead into aft fuselage

Part 1 -- Pre-test Helium Injection Test at 6, 12 and 25 scim for Test Hoses 1,2, and 3

After the completion of the leak checks for the installed LH2 flexhoses, the aft helium concentration was allowed to stabilize, and a baseline ambient helium reading was recorded.
Then via a portable regulator panel, helium was injected into the aft fuselage thru T/H#1 into the aft near the SSME purge duct at a specific flow rate of 6 scim and the helium delta after stabilization was recorded. The flow rate was then adjusted to deliver 12 scim and again a stabilized delta helium concentration was recorded. Lastly the flow rate was adjusted to 25 scim and the final stabilized reading for TH#1 was taken. The aft fuselage was then opened and the helium concentration allowed to return to the baseline ambient reading. During this time the mass spec machine would be optimized or the HGDS recalibrated. This was repeated for TH#2 (disconnect area) and TH#3 (FCV valves).

A graph containing a calibration line was plotted for each test hose using the three points and with plus or minus error bands. In the V1201 OPF test, the calibration line points were determined by multiplying the mass spec machines sensitivity by the delta GHe concentration. The error bands were determined by the mass spec machines uncertainty multiplied by the machines sensitivity. In the V1202 vertical test, the calibration line points were determined by plotting corrected aft deltas (raw delta corrected for test, span, and zero gas drifting) against the helium injection flow rates. The error bands were placed plus and minus one scim above and below the calibration line.

V1201 Sample Calculations

Test Hose TH1

Pretest Injection Background:	350 ppm
M/S sensitivity	2.5×10^{-9}
M/S Uncertainty:	+/-10
6 scim GHe delta:	60
12 scim GHe delta:	128
25 scim GHe delta:	240

6 scim data point:
$(60) * (2.5 \times 10^{-9}) = 1.5 \times 10^{-7}$

12 scim data point:
$(128) * (2.5 \times 10^{-9}) = 3.2 \times 10^{-7}$

25 scim data point:
$(240) * (2.5 \times 10^{-9}) = 6.0 \times 10^{-7}$

Uncertainty Error Band:
$(20) * (2.5 \times 10^{-9}) = 0.5 \times 10^{-7}$

A best fit line is drawn thru the three data points with a plus or minus 0.5 error band included. See Figure 1 - 1.

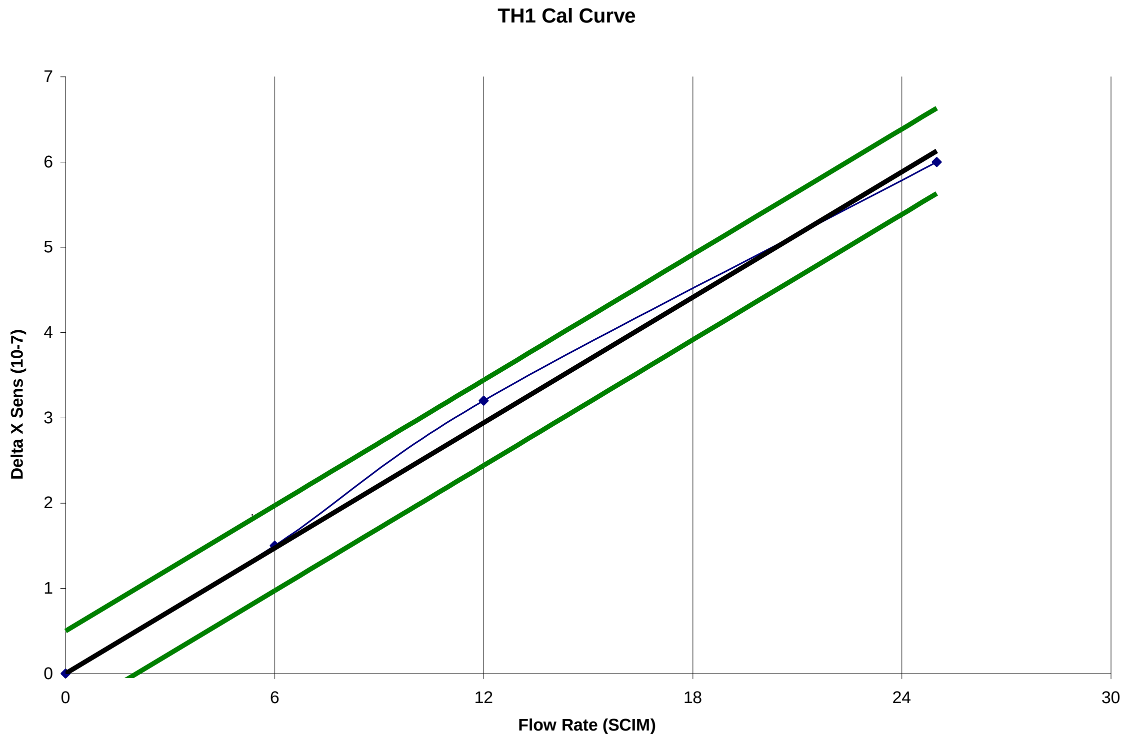


Figure 1 - 1

Part 2 -- System Pressurization

Following completion of the calibration runs, each MPS system (GH2, LOX and Hot Gas, GO2, LH2) is pressurized and the helium delta from an ambient reading is obtained. After each system is pressurized and then secured, the aft fuselage must be reopened, helium concentration allowed to stabilize at ambient, aft reclosed, sensing units recalibrated and a new baseline reading obtained prior to starting the next system pressurization.

The delta helium concentration obtained for a system is then plotted on the Calibration curve (usually TH#1 is used as it provides the most conservative and best yield based on the mixing characteristics) and a worst case leakage is obtained.

GO2 Pressurization Test

Pretest Background:	370 ppm
M/S sensitivity	2.7×10^{-9}
M/S Uncertainty:	+/-10
GO2 Test GHe delta:	70
Mixing Factor:	1.25

GO2 Test data point:
$(70) * (1.25) * (2.7 \times 10^{-9}) = 2.36 \times 10^{-7}$

Uncertainty Error Band:
$(20) * (2.7 \times 10^{-9}) = 0.54 \times 10^{-7}$

Data point is plotted on TH1 cal curve and extrapolated to the worst case error band to yield maximum leakage. See Figure 1 - 2.

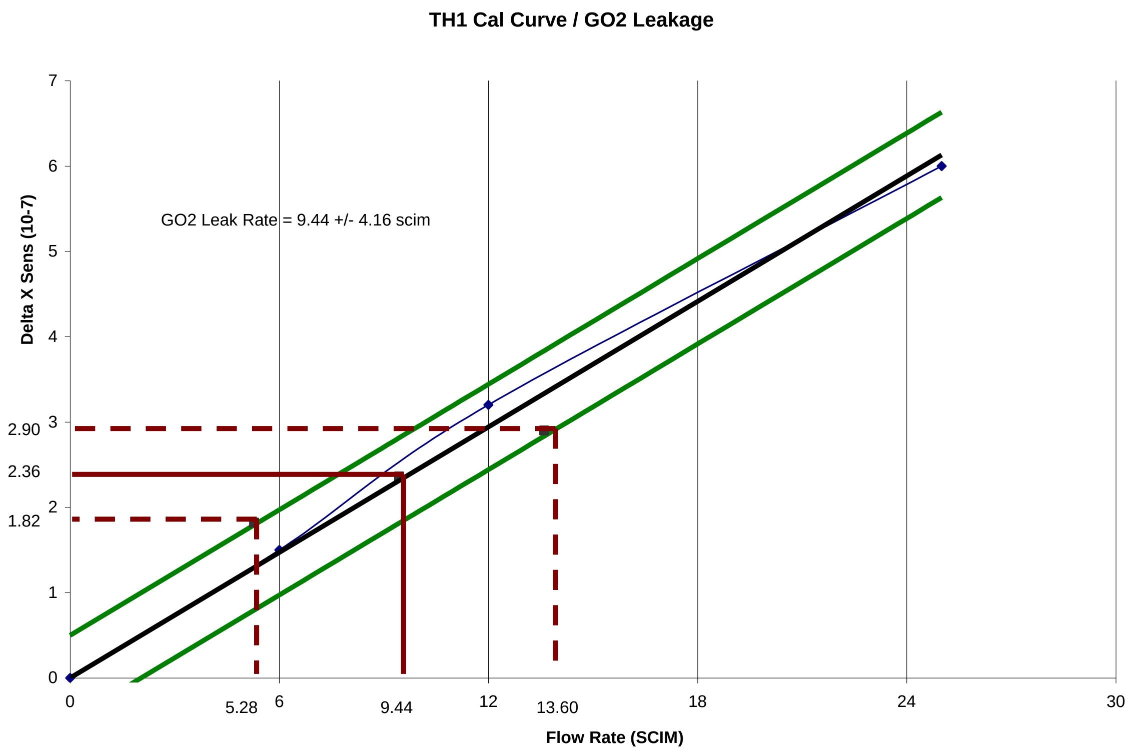


Figure 1 - 2

Part 3 -- Post-test Helium Injection Test at 6, 12 and 25 scim for Test Hoses 1,2, and 3

The same process used in the pre-test calibration tests is repeated post test to verify the delta helium concentration points fall within the pretest constructed calibration cures.

Interim Iterations

These early tests were time consuming, the induced errors great, and the data did not lend itself well to trend analysis. Over the years the V1201 test was dropped due to mass spectrometer instability, Helium background intrusion/isolation problems, schedule time constraints (a redundant test whose results were not as accurate as its vertical sibling) and the V1202 test has been streamlined mostly due to HGD system improvements but also via:

- No longer configuring the LH2 sub systems with flexhoses and the accompanying pre-test leak checks. Now the topping valve is opened using nitrogen at the actuator.
- With the better understanding of the aft fuselage mixing properties the three pre and post test injection tests have been dropped with only a single 6 scim post test verification test using TH1 being necessary to verify the test results.
- All systems are now pressurized back to back with a real time HGD generated graphical signature time stamped for start of individual system pressurization. Standardizing of the test lends well to data analysis.
- HGD HUMs system incorporation which can be used to divert external PD4/PD5 leakages from reentering the aft fuselage and distorting test data.
- Total leak rate now calculated using a simpler formula based on aft purge flow rate and change in GHe concentration.

Present Test

- Preops have been streamlined -- easy to install shop aid vent door enclosure, use of TSM utility panel as GHe/GN2 drag on pressure source, LH2 system sub-systems linked by opening PV13 with GN2 (requirement deleted for Hi pt bleed pressurization),
- Test performed without any precals or cal curve generation (6 to 8 hour savings)
- All systems pressurized back to back with one overall leakage calculation -- still retains the visibility to determine need for system isolation leakage investigation (6 to 8 hour savings).
- One post test GHe injection run at 6 scim is performed to verify sampled scim leakage at vent door does equate to input scim leakage.
- Other leak checks incorporated seamlessly into Test -- HUMs PD4/PD5 interface test with doors open and closed (PD5 now performed at 500 psig), SSME Ball Valve leak checks.

- ➢ New S72-0685-06 Panel eases pressurization and venting of pre-press systems post blanking plate installation.

Data is easy to interpret and leads to easy trend analysis. See Figure 1-3.

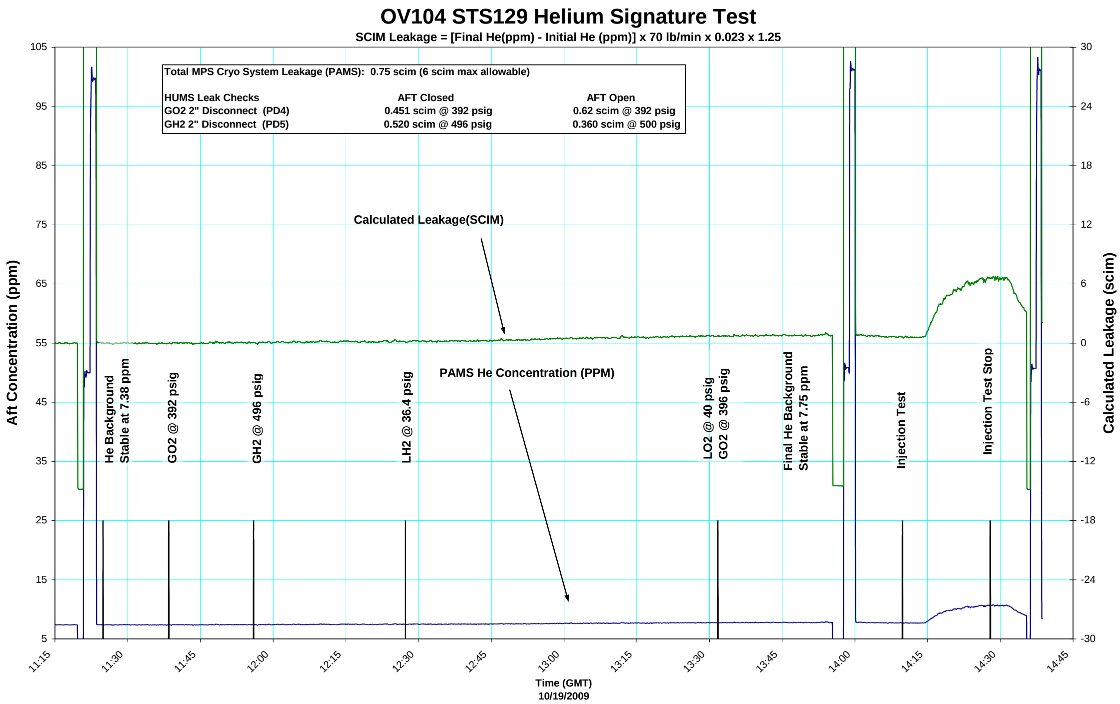
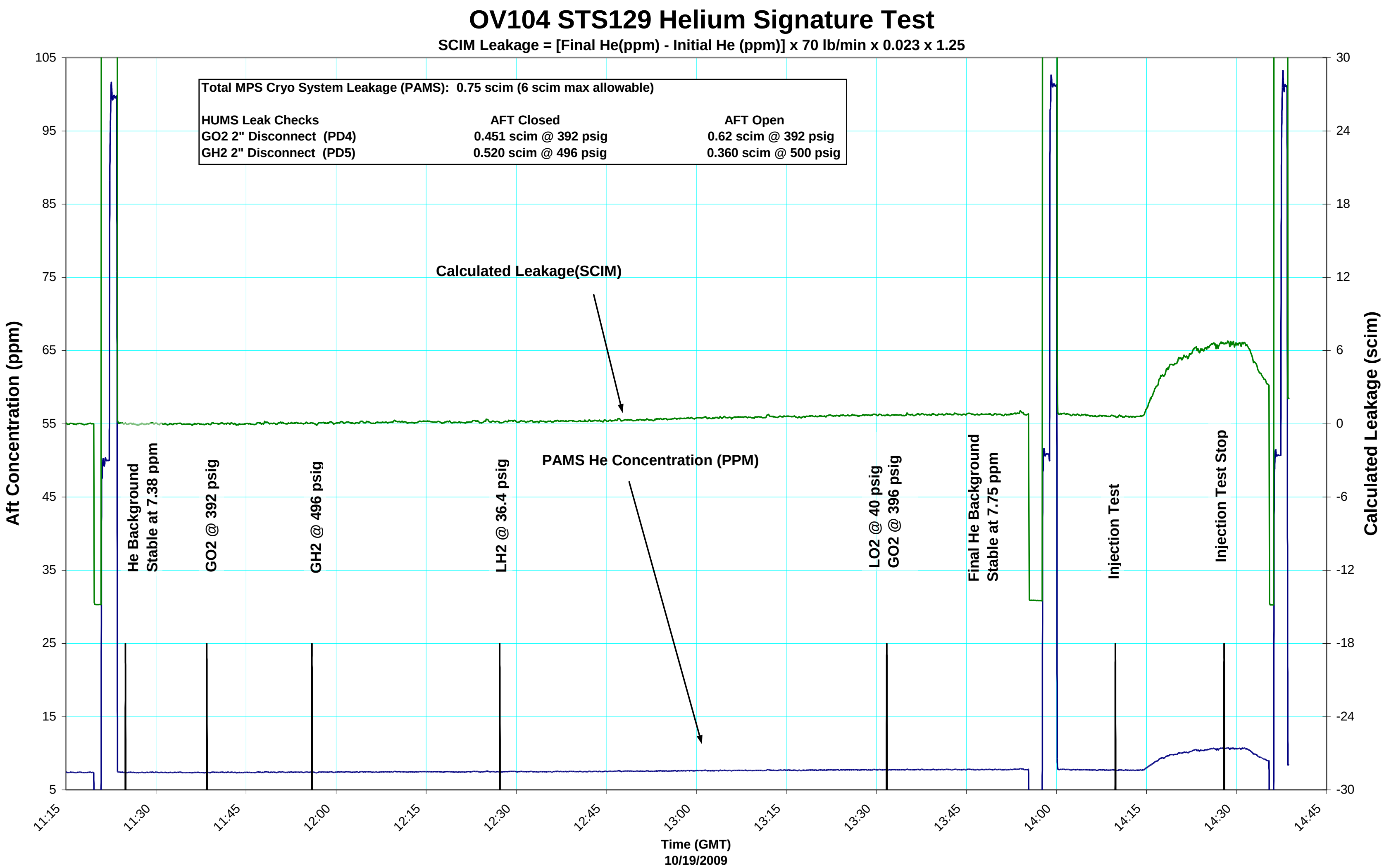


Figure 1 - 3

Conclusion

Over the years, the HST has been reduced from a multiple orientation test to a vertical only test. Lessens learned and test repeatability have resulted in many realized efficiencies that have shortened the test from a 36 hour test to a 6 hour test and have also improved the fidelity of the test to where a high confidence can be placed on the likelihood that the identified scim leakage is a true reflection of the present total MPS cryogenic/high pressure system leakages.



OV104 STS129 Helium Signature Test
SCIM Leakage = [Final He(ppm) - Initial He (ppm)] x 70 lb/min x 0.023 x 1.25
Total MPS Cryo System Leakage (PAMS): 0.75 scim (6 scim max allowable)
HUMS Leak Checks
AFT Closed
AFT Open
GO2 2" Disconnect (PD4)
0.451 scim @ 392 psig
0.62 scim @ 392 psig
GH2 2" Disconnect (PD5)
0.520 scim @ 496 psig
0.360 scim @ 500 psig
Calculated Leakage(SCIM)
PAMS He Concentration (PPM)
He Background Stable at 7.38 ppm
GO2 @ 392 psig
GH2 @ 496 psig
LH2 @ 36.4 psig
LO2 @ 40 psig
GO2 @ 396 psig
Final He Background Stable at 7.75 ppm
Injection Test
Injection Test Stop
Aft Concentration (ppm)
Calculated Leakage (scim)
105
95
85
75
65
55
45
35
25
15
5
30
24
18
12
6
0
-6
-12
-18
-24
-30
11:15
11:30
11:45
12:00
12:15
12:30
12:45
13:00
13:15
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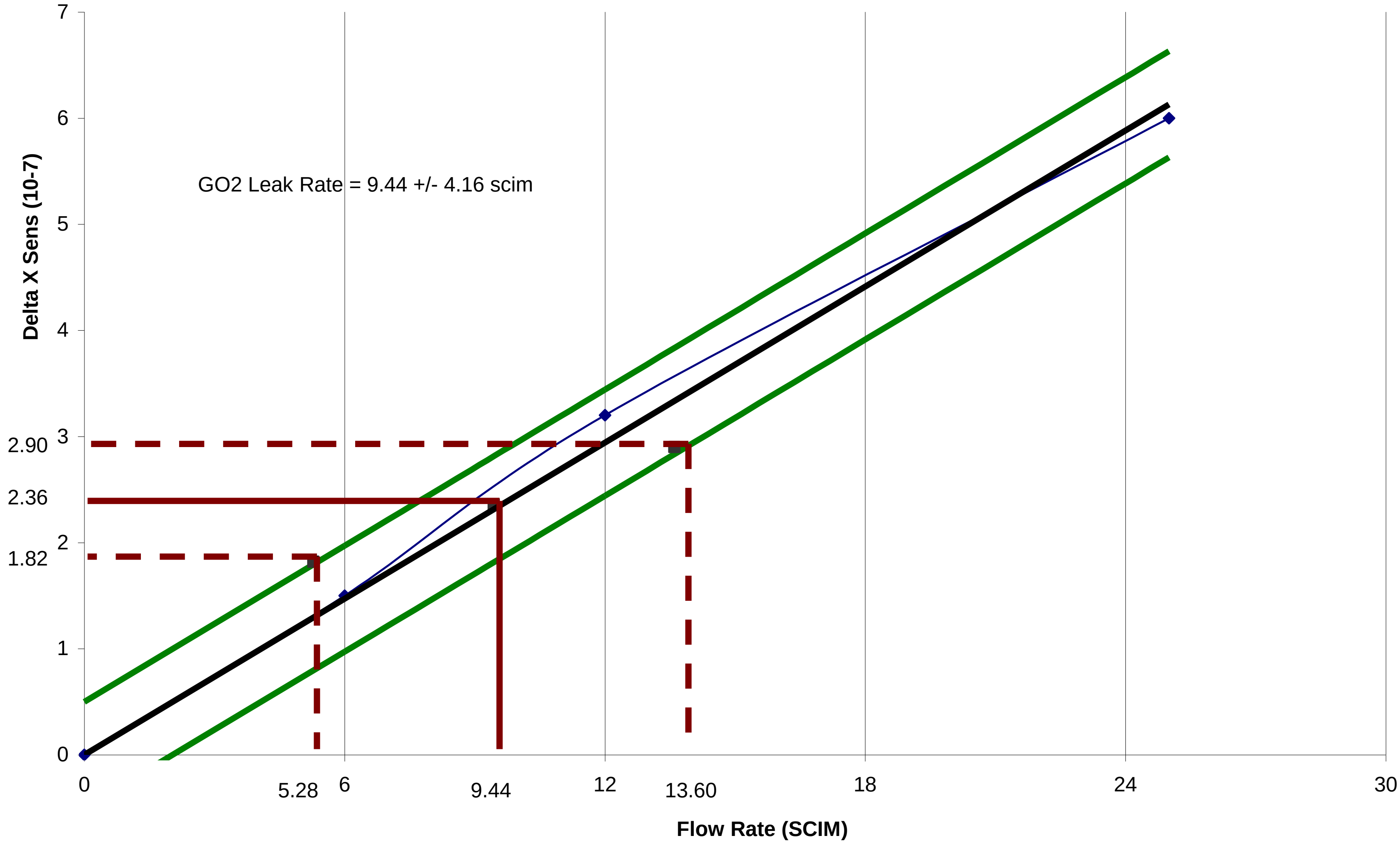
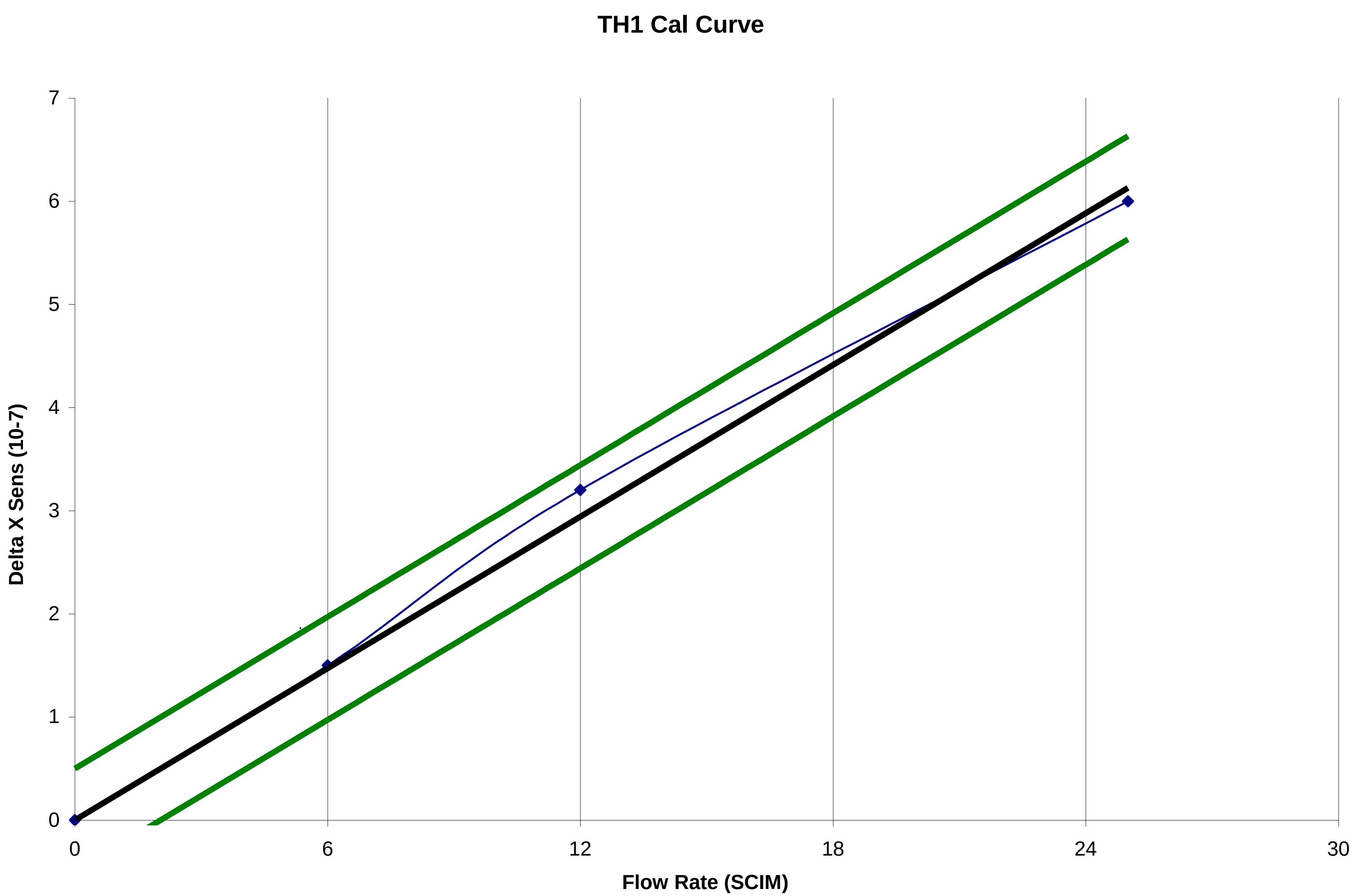
TH1 Cal Curve / GO2 Leakage




TH1 Cal Curve
Delta X Sens (10-7)
Flow Rate (SCIM)
0
1
2
3
4
5
6
7
0
6
12
18
24
30